IDENTIFICATION OF NOISE SOURCES ON LONGWALL PANELS USING MULTIPLE TIME-SYNCHRONIZED DOSIMETERS

E. Spencer, NIOSH, Pittsburgh, PA
D. Babich, NIOSH, Pittsburgh, PA
L. Alcorn, NIOSH, Pittsburgh, PA
A. Smith, NIOSH, Pittsburgh, PA

Abstract

Noise is one of the most pervasive health hazards in mining. A compilation of Mine Safety and Health Administration (MSHA) noise survey data for Fiscal year 1990 shows that approximately 40% of the total samples taken for longwall occupations exceeded the Permissible Exposure Limit (PEL) of 100% [Gigliotti et al. 1991]. In order to properly determine workers' exposures on longwall coal mining systems, it is necessary to provide accurate baseline measurements for these mining systems. This research was designed to develop guidelines and test procedures for identifying all noise sources that are major contributors to the underground noise exposure of longwall coal mining system workers. Once the high noise sources are identified, promising engineering controls can be tested and evaluated to reduce the noise of the sources. The measurement system used to analyze the noise sources included stationary dosimeters in a documented repeatable pattern and a time-motion study of the cutting cycle and operator's work cycle. Significant results from the underground measurements show that the highest sound levels recorded are at the stageloader discharge segment and tailpiece controls and remained at about the same level throughout the test.

Introduction

Overexposure to noise remains a widespread, serious health hazard in the U.S. mining industries despite 25 years of regulation. Noise induced hearing loss (NIHL) is the most common occupational illness in the U.S. today, with 30 million workers exposed to excessive noise levels [NIOSH 1999]. Noise doses (PEL) up to 786% have been recorded for longwall coal mining system workers in jobs with titles such as shearer operator, jacksetter, longwall foreman, and headgate (stageloader) operator [Bauer et al. 2001]. This study revealed that the sound levels around the longwall mining system ranged from 81 dB(A) to 102 dB(A). The study also showed that the stageloader operators were among the most exposed longwall coal mining system workers, with recorded PEL dose levels ranging from 142% to 386%.

This paper presents suggested measurement methods from research done by the NIOSH Pittsburgh Research Laboratory to reduce noise exposure in mining environments. The measurement methods and test procedures are needed to identify noise sources that are major contributors to the underground noise exposure of longwall mining system workers. The procedure will allow for accurate, repeatable measurements of the noise sources for the development and evaluations of noise controls on longwall mining systems. Specifically, this paper concentrates on the noise emissions of a DBT America longwall system. Mention of any company or product does not constitute endorsement by NIOSH. DBT America longwall systems are representative of industry usage making up approximately 40% of the systems in use in underground coal mines [Coal Age 2006]. This information is intended for use by mining equipment manufacturers, mining companies, and MSHA for evaluating the effectiveness of engineering noise controls.

Background

A study evaluating an engineering noise control on a JOY stageloader in New Mexico was completed by NIOSH researchers in 2004 [Bauer et al. 2005]. The study was performed in three phases: precontrol, postcontrol, and 6-month postcontrol. The control tested included sound absorptive filled cavities on the crusher and gooseneck using bagged fiberglass covered with conveyor belting. The sound levels, worker noise exposure, and four stationary dosimeter measurements were collected at similar locations and conditions for all phases. The sound level measurements made in the headgate area and along the length of the stageloader were taken at 30 locations using a sound level meter set to average over a 30-second time period. Thus, a minimum 15-minute test period was required when mining conditions were constantly changing. The 6-month postcontrol sound levels were on average 2–3 dB less than the initial postcontrol sound levels and nearly the same as the precontrol sound levels. Overall, it was not possible to determine if the implemented engineering noise control reduced the stageloader sound levels or the stageloader operator noise exposure.

Although various types of measurements were conducted on the stageloader over several shifts, the test results varied and were inconclusive. At this study site, production levels varied greatly because of problems associated with Hydrogen Sulfide (H_2S). This resulted in widely varying amounts of coal in the stageloader because production was decreased or stopped when the concentration of H_2S in the environment reached a certain level. Thus changing amounts of coal being cut, crushed, and conveyed was a major factor in the variability of the testing results. In addition, the movement of the longwall face in relation to the crosscuts, and the varying size of the section caused deviations in the long-term or shift measurements. The high percentages of noise overexposures and wide ranges of dose levels and the inability to evaluate noise controls underground prompted NIOSH to perform research to determine methods and procedures for measuring the longwall mining systems underground.

Research Approach

Prior studies have concentrated on exposure/dosage measurements and single sound level measurements as indicators of the excessive noise problems on longwall mining systems. This study's suggested measurement methods included: 1) using time-synchronized stationary dosimeters for measuring sound levels of the longwall mining system, and 2) conduct a time-motion study. The time-motion study was used in conjunction with sound level measurements to correlate operational events on the longwall mining system with periods of high noise generation. This allowed for repeatable measurement of noise sources on longwall mining systems for pre- and postnoise control evaluations.

Permissible dosimeters were used to record the sound levels and were placed on the stageloader and headgate area in a documented pattern (Figure 1). Because of the size of the stageloader, the stationary dosimeters were placed at known noise sources on the stageloader, (e.g., armored face conveyor (AFC), crusher, and discharge). The dosimeters were fitted on magnetic stands with their microphones approximately 46 cm (18 in) from the magnet base. Any height greater than this may have resulted in the instruments being knocked off or crushed because of the low clearances. Each dosimeter was set to record the equivalent sound level every 10 seconds using an exchange rate of 3-dB, A-weighting, slow response, 40-dB threshold level, and 140-dB upper limit. Data recorded from the dosimeter provided the following information: an A-weighted sound pressure level, maximum and minimum sound levels, and absolute unweighted peak sound levels at each of the designated positions. To obtain the MSHA PEL and time weighted average over 8 hours [TWA(8)], the dosimeters were also set to MSHA criteria which included a 5-dB exchange rate, A-weighting, slow response, 90-dB threshold level, 90-dB criteria level and 140-dB upper limit. [64 Fed. Reg. 49548 (1999)].

A time-motion study in conjunction with these measurements was conducted by two researchers. One researcher was positioned at the headgate and was responsible for recording the shearer position and the status of the AFC (off or running empty, half-full, or full) with time and distance. The other was positioned at the stageloader discharge area and was responsible for the stageloader armored conveyor (AC) status (off or running empty, half-full, or full), the stageloader operator's position, and the movement of the stageloader with time and distance. The dosimeters, and the watches used for the time-motion study, were time synchronized.

Test Plan

In order to determine the dosimeter locations, distance measurements of the longwall mining system were made underground. These locations were marked and recorded with reference dosimeter numbers, as shown in Figure 1 (see Appendix). The 12 preprogrammed dosimeters were attached to magnetic stands then placed at the predetermined locations. Once all the dosimeters were in position and the researchers were positioned for the time-motion study, the testing then began.

Testing consisted of monitoring two complete passes (a pass consisted of the shearer cutting down to the tailgate and back), or cutting cycles of the longwall mining system. During a complete pass the shearer traveled a distance of 615 m (2,000 ft) in 80 minutes, which correlates to an average cutting speed of about 7.7 m (25 ft) per minute. The cutting speed was less than 7.7 m (25 ft) per minute during cutout and sump-in at the head and tail, and greater when traversing the remainder of the longwall face. After 4 hours, the dosimeters were removed from the longwall mining system and taken back to the lab for analysis. Each dosimeter was downloaded and saved as an Excel file. After all of the results were tabulated into an Excel spreadsheet and analyzed, relationships between the data were determined. A graph was generated for each test point plotting the equivalent sound level versus time. Then the time motion results were overlaid on each of the graphs. From these graphs, the maximum sound level for each location could be determined and related to the operation of the longwall mining system.

Results

In order to analyze the complex longwall mining system, the headgate and stageloader was divided into six measurement segments: the shearer, stageloader headgate, swivel pans/crusher, trough pan assembly (stageloader body), stageloader operator position, and discharge/ tailpiece controls. The data was then organized so that the sound levels in each segment could be examined as a function of time. Operational events that were noted during the time-motion study were analyzed on the same time scale as the stationary noise measurement instruments. Thus, insight was gained about the sound field as the longwall system operated.

Shearer Measurement Segment

Figure 2 starts with the shearer measurement area segment, locations 1 and 2, which represents the shearer as it travels to the headgate, cuts out and sumps into the face, then cuts back to the tailgate. Both locations have similar sound levels when the shearer is at the headgate area (dash-dot line) indicating that the shearer is the dominate noise source. The sound levels at location 1 drop by 8 dB, 10 minutes after the shearer leaves the headgate area, at which time only the sound levels generated by the AFC are present. However, the sound levels at location 2 stay consistently higher then location 1 except when the shearer is at the headgate. This indicates that location 2 receives additional noise from the conveyor/head drive area section, which is the major noise contributor at location 2 when the shearer is at a distance down the face from the headgate.

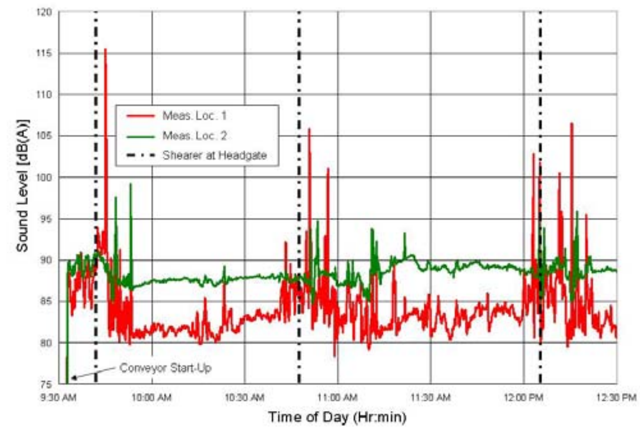

Figure 2. Sound level measurements at shearer measurement segment, locations 1 and 2.

Stageloader Headgate Segment

Sound level results for measurement locations 3 and 4, which represent the stageloader headgate area, are shown in Figure 3. This segment is where the AFC ends and the stageloader AC starts. The startup noise from the face AFC (head drive) and shearer can be seen at 9:32 AM in this graph and continues until 9:45 AM as the shearer cuts into the headgate. The start up noise diminishes as the conveyors fill and the machine "sumps-in". High peaks occurred at 9:48 AM, 10:51 AM and 12:05 PM when the shields push the stageloader forward. Other peaks at 10:45 AM and 11:59 AM correspond to the shearer cutting at the headgate. In general, the dominate noise sources in this case are when the shearer is at the headgate, when the stageloader is moved, and finally, from the AFC head drive and the noise from both conveyors, after the shearer leaves this area.

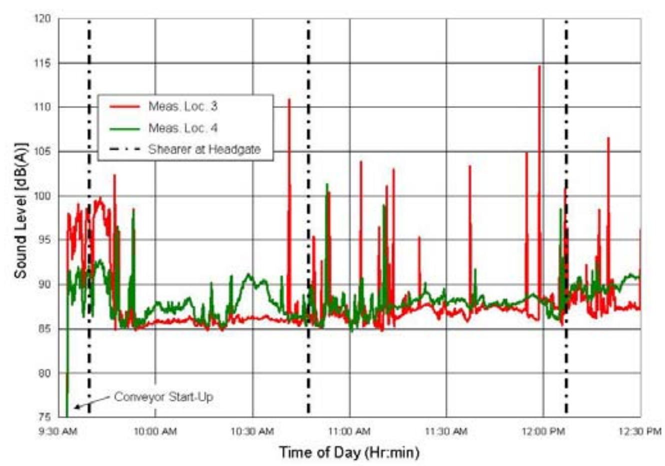

Figure 3. Sound level measurements at stageloader headgate segment, locations 3 and 4.

Swivel Pans/Crucher Segment

Figure 4 shows sound level results for locations 5 and 6, which represents the area in front of (swivel pans), and on top of the crusher respectively. The results show sound levels primarily ranging from 95 dB(A) to 105 dB(A). Initially, when the conveyors went from empty to half-full to full, a corresponding rise in the sound levels was observed. However, as time went on no correlation between increases in sound level and conveyor status (empty, half-full, or full) could be determined. Furthermore, shearer location had little impact on noise levels observed at these measurement positions due to the distance from the shearer. In general, at these locations, the dominate noise sources are caused by the crushing and transport of material, along with the machinery noise.

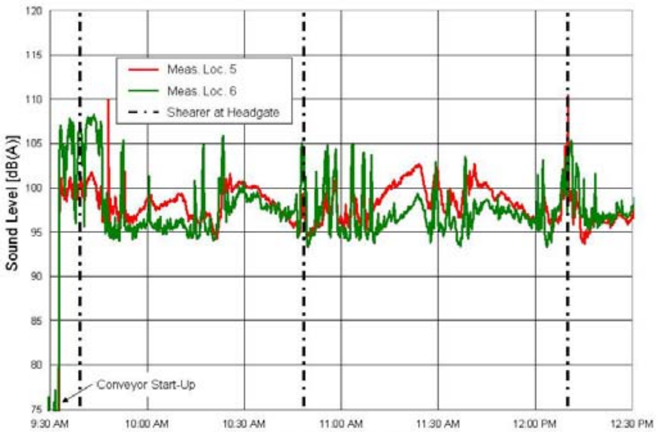

Figure 4. Sound level measurements at swivel pans/crusher segment, locations 5 and 6.

Trough Pan Assembly (Stageloader Body) Segment

Figure 5 shows sound level results for locations 7 and 8, which represent the area on the body of the stageloader at the trough pan assembly and nearby the stageloader body. The sudden increases at each location, from 10:25 AM to 10:45 AM cannot be explained by the time-motion observations. Further investigations are needed to determine the cause of this event. The approximate 4–5 dB difference in sound level between locations 7 and 8 can be attributed to location 7 being on the stageloader body and closer to the noise radiating from the enclosed body. At these locations, the dominate noise sources are caused by the crushing and transport of material, along with the machinery noise.

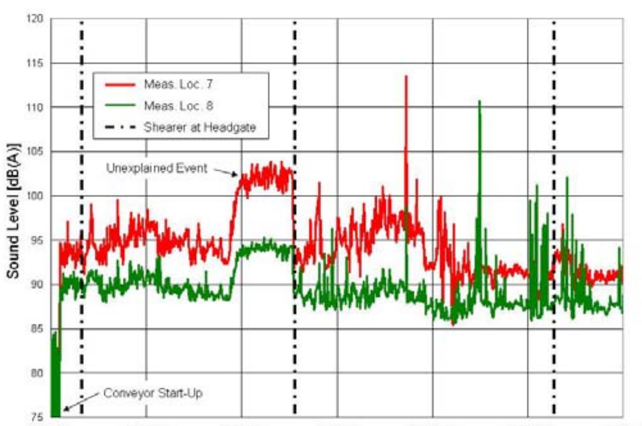

Figure 5. Sound level measurements at trough pan assembly segment, locations 7 and 8.

Stageloader Operator Position Segment

Figure 6 shows sound level results for measurement locations 9 and 10, which represent the area at the stageloader operator's position. As Figure 6 shows, the stageloader operator spent about 50% of his time in this area (shaded area). Similar to what occurred at locations 7 and 8, the sudden sound level increase at location 9 from 10:25 AM to 10:45 AM cannot be explained by the time-motion observations. The total MSHA-defined dose during the total observational period, at location 10 taken directly from the dosimeter, was determined to be 28% with a time-weighted average [TWA(8)] of 81 dB(A). The dominate noise source in this area is caused by the transport of material radiating from the stageloader body.

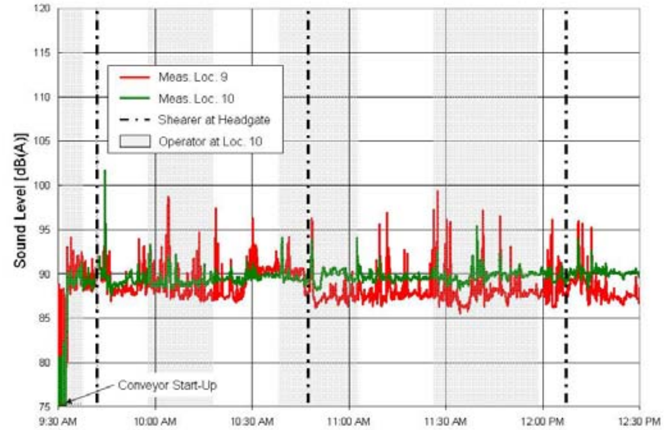

Figure 6. Sound level measurements at stageloader operator position segment, locations 9 and 10.

Discharge/Tailpiece Controls Segment

Sound level results for measurement locations 11 and 12 are displayed in Figure 7, and represent the area at the discharge segment of the stageloader. The controls for the crawler-mounted tailpiece are also located in this area. The dosimeter and magnetic stand, at location 11, fell off of the stageloader at 9:52 AM and was placed back into position at 10:04 AM. This measurement segment had the highest sound levels of all measurement locations along the stageloader ranging from 105 dB(A) to 111 dB(A). Although the operator did not spend a majority of his time in this area (shaded area), exposure levels would likely exceed the Permissible Exposure Level (PEL). Using the MSHA criteria, the total accumulated dose during the cutting cycle between 10:46 AM and 12:10 PM at location 12 is 1,195% and the TWA(8) is 108 dB(A) for this cutting cycle. In general, the dominate noise sources was caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting like a wave-guide and making it louder at the discharge. External to the discharge noise source are the tailpiece motor and gear box contributions.

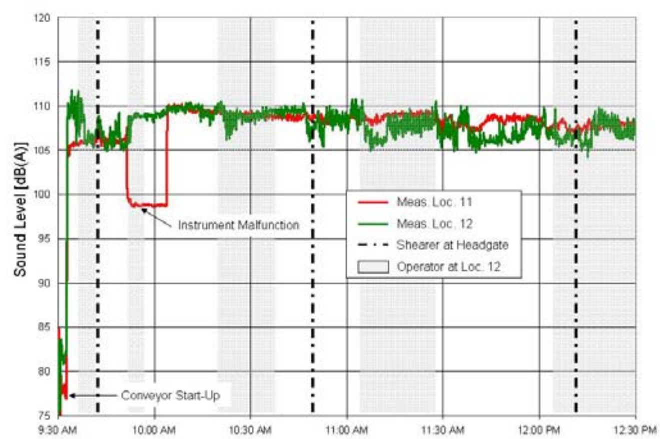

Figure 7. Sound level measurements at discharge/ tailpiece controls segment, locations 11 and 12.

Segment Comparison Analysis

Analysis of data from a cutting-cycle between 10:46 AM and 12:10 PM is shown in table 1 (see Appendix). The results compare all the measurement locations by the MSHA dose, TWA(8), and overall equivalent sound level. The information presented in table 1 is based strictly on the 1 hour 24 minute time period (cutting cycle), extrapolated to 8 hours, and assumes that the cutting cycle and associated sound levels repeat exactly the same for an 8-hr. period.

When the shearer is at the headgate, sound levels peak above 105 dB(A) (Figure 2), however these peaks have a minimal effect on the calculated dose because of their short duration. It is not until the crusher segment area that the high dose levels and corresponding high dB(A) TWA(8) occur. The 14-dB difference between location 7 and 8 can be attributed to location 7 being on the stageloader body and closer to the noise radiating from the enclosed body. The stageloader operator position, at the mid-point of the stageloader body, is a relatively quiet area for the operator. The operator should be encouraged to be in this area.

Unlike any other location along the stageloader, the discharge and the area around the tailpiece controls have excessively high sound levels, during this cutting cycle, resulting in potentially high doses for a worker located near this area during this cutting cycle. This noise at the discharge is caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting like a wave-guide and making it louder at the discharge, along with the tailpiece motor and gear box.

Disclaimer

The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Summary

This paper presents suggested methods for repeatable measurements of noise levels of a longwall mining system for pre- and post noise control evaluations. In addition, the report documents research by NIOSH on a longwall mining system representative of industry usage. The study involved monitoring the headgate area and stageloader using stationary time-synchronized dosimeters set-up to record sound levels. The synchronized dosimeters allowed for sound levels, dose, and TWA(8) comparisons along the entire stageloader, from each measurement location. A time-motion study of the shearer, stageloader movement, stageloader operator, and amount of material on the conveyor was conducted to correlate operational events on the longwall mining system with periods of high noise generation. The shearer's position had minimal effect on the overall sound levels, as did the stageloader movement. The estimated MSHA 8-hr dose listed in table 1 indicates that the stageloader operator is not likely to be overexposed at the operator position, but when at the tailpiece controls, the potential for overexposure was excessively high. Initially, when the stageloader AC went from empty to half-full to full, a corresponding rise in the sound levels was observed. However, as time went on no correlation between increases in sound level and conveyor status (empty, half-full, or full) could be determined.

Identifying noise sources is the first step toward developing engineering noise controls to reduce longwall mining system workers' noise overexposure. The highest equivalent sound levels recorded are at the stageloader discharge segment and tailpiece controls; these remained at about the same level throughout the test. The next step is to identify the sources causing the noise at the discharge end of the stageloader, since during the cutting cycle it produced the highest calculated TWA of 109 dB(A). The noise at the discharge was caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting like a wave-guide and making it louder at the discharge, along with the tailpiece motor and gear box. Because the discharge area has proven to have the highest sound levels, future engineering noise control research by NIOSH will be concentrated in this area.

References

1. Gigliotti, S.J., C.A. Davis, G. Niewiadomski, J.E. Tisdale and P.M. Turcic (1991), "Review of Longwall Mining in the United States Relative to Health and Safety," in *Proceedings of the Longwall USA International Exhibition & Conference*, Overland Park, KS: Intertec Publishing Corp., pp. 51–69.

2. NIOSH (1999), "Fact Sheet: Work-Related Hearing Loss," Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

3. Bauer, E.R., D.J. Podobinski and E.R. Reeves (2001), "Noise exposure in longwall mining and engineering controls research," in *Proceedings of Longwall USA International Exhibition & Conference*, Overland Park, KS: Intertec Publishing Corp., pp. 51–69.

4. Coal Age (2006), "U.S. Longwall Census 2006 - Coal Companies Invest in More Longwall Capacity," S. Fiscor, Editor-in-Chief. Vol. 111, No. 2, February 2006, pp 26-30.

5. Bauer, E.R., E.R. Reeves, T.M. Durr, D.R. Zuchelli and D. Armour (2005), "Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader," in *SME Preprint 05–58,* Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

6. 64 Fed. Reg. 49548 (1999), "Health Standards for Occupational Noise Exposure; Final Rule," *30 CFR,* Parts 56, 57, et al.

Appendix

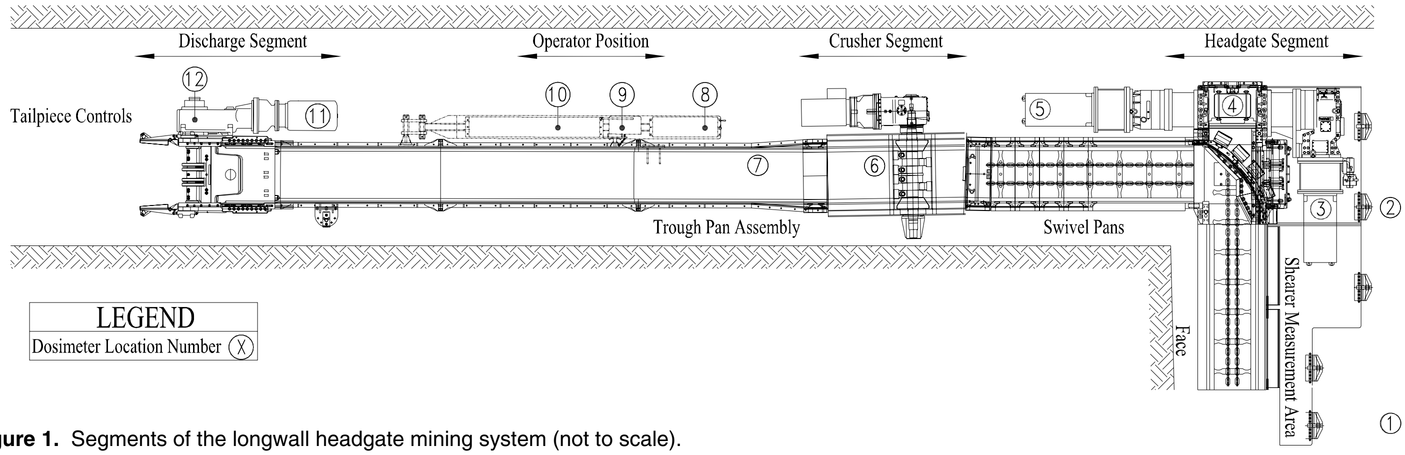

Figure 1. Segments of the longwall headgate mining system (not to scale).

Table 1. Measurement results from cutting-cycle between 10:46 AM and 12:10 PM.

Segment Area	Measurement location	MSHA-defined dose, %	MSHA-defined TWA(8)	Overall Test Leq
Shearer Measurement Area	1	9	73 dB(A)	84 dB(A)
Headgate	2	10	74 dB(A)	89 dB(A)
	3	24	80 dB(A)	88 dB(A)
Crusher	4	6	70 dB(A)	88 dB(A)
	5	361	99 dB(A)	99 dB(A)
Trough Pan Assembly	6	308	97 dB(A)	97 dB(A)
	7	187	94 dB(A)	94 dB(A)
Operator Position	8	26	80 dB(A)	87 dB(A)
	9	15	76 dB(A)	88 dB(A)
Discharge and Tailpiece Controls	10	35	82 dB(A)	90 dB(A)
	11	1,358	109 dB(A)	108 dB(A)
	12	1,195	108 dB(A)	107 dB(A)